concentration observed in this species in a similar translocation experiment in 1985 (5 ± 2 $\mu g/g$). In contrast to all earlier studies, and to the oyster transplant study in 1995, mean selenium concentrations in *P. amurensis* in late 1995 and early 1996 were 15 ± 3 $\mu g/g$. This is two to three times greater than mean selenium concentrations observed in earlier studies in the same location. The higher concentrations are especially significant in that they substantially exceed values (about 10 $\mu g/g$) that convincingly reduce growth or cause reproductive damage when ingested in experiments by birds and fish (Hamilton *et al* 1990; Heinz *et al* 1989). Thus, selenium exposures of birds and fish that depend on bivalves for food have probably dramatically increased since the latter 1980s to levels likely to be of concern to ducks and sturgeon. However, no direct studies of selenium concentrations in the resource species have been conducted since 1990.

A mixture of factors could contribute to the change in selenium exposures in Carquinez Strait. First, *P. amurensis* could be an organism that is more efficient at accumulating selenium than the previous resident species. So the higher selenium concentrations in this clam could be a function of the biology of this exotic species. Studies similar to those conducted by Luoma *et al* (1992) with *Macoma balthica* are needed to determine if bioaccumulation of selenium by *P. amurensis* is unusual. It is also possible that selenium discharges to North Bay increased between the late 1980s and 1995-1996. Potential sources of selenium include refinery inputs and inputs from the San Joaquin River and western Central Valley. Studies of dissolved and particulate selenium concentrations and speciation have been particularly effective in resolving sources of selenium inputs to Suisun Bay (Cutter 1989). Two surveys from 1995-1996 are being analyzed, but ongoing monitoring of these concentrations is probably warranted. A fourth possibility is that residual selenium in the ecosystem, caused by past contamination, is being recycled more intensely than in the past. There is no evidence to support this conjecture, but studies of processes that affect selenium recycling from sediments would be valuable. Whatever the factors that contribute to the elevated concentrations of selenium presently observed in this ecosystem, ongoing monitoring of water concentrations and *P. amurensis* will be necessary to understand the long-term trajectory of these trends and to better understand how the contamination might be affecting upper trophic level organisms.

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Contaminants and Their Potential Effects at the Rivers Confluence and Northern Estuary

Bruce Thompson and Jay Davis, San Francisco Estuary Institute

The San Francisco Estuary Regional Monitoring Program has been monitoring contamination in water, sediments, and transplanted bivalves throughout the lower San Francisco estuary since 1993. Overall, 24 stations are sampled, and numerous trace elements and organic contaminants are measured two or three times annually. This article summarizes some of the results believed to be of particular interest to Interagency *Newsletter* readers. Full reports or datasets are available through SFEI or at our web site (http://www.sfei.org).

Contaminants in Water

In the Regional Monitoring Program, water samples are collected three times each year for analysis of trace element and trace organic contaminants. For some trace elements measured, data from the Regional Monitoring Program can be combined with data generated before the program under the Bay Protection and Toxic Cleanup Program (BPTCP) to form a continuous dataset from 1989 to the present. As an example, mercury data from four RMP stations in the northern estuary (for locations, see Figure 1) are shown in Figure 2. Mercury is typical of many trace elements that associate with sediment particles. Fluctuations in mercury concentrations in estuary water closely follow fluctuations in total suspended solids. TSS concentrations were higher at Grizzly Bay than at the other stations included in Figure 2. Long-term trends for elements like mercury are masked by variation in TSS.

In 1993, the Regional Monitoring Program began monitoring for other elements, such as selenium. Selenium represents a different group of elements that occur primarily in dissolved form in the estuary. Selenium concentrations in the northern estuary showed a different pattern than mercury, with similar concentrations at the four northern estuary stations (Figure 3). The only station that showed a somewhat distinct pattern was the San Joaquin River station.

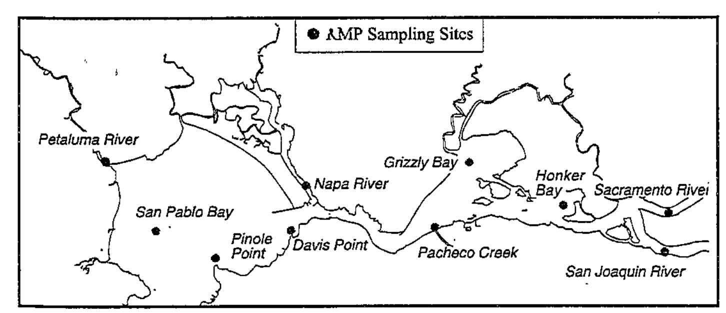

Figure 1
REGIONAL MONITORING PROGRAM SITES IN THE NORTHERN ESTUARY

Regional Monitoring Program water samples are also analyzed for a large number of organic contaminants, including PCBs (polychlorinated biphenyls), organochlorine pesticides, PAHs (polycyclic aromatic hydro-

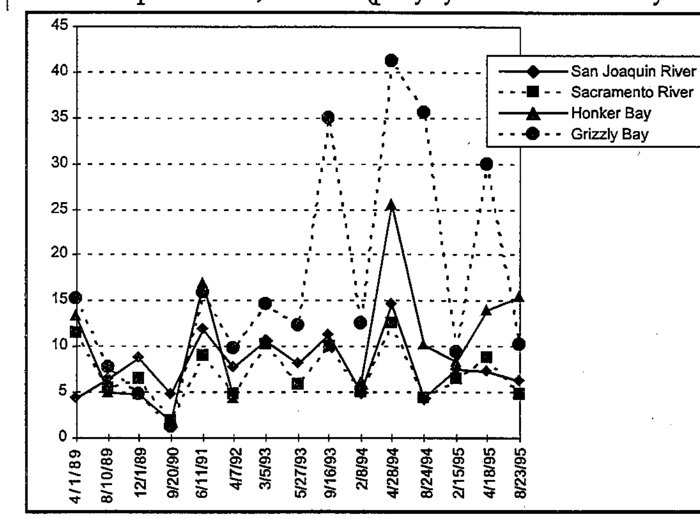

Figure 2
MERCURY CONCENTRATIONS IN NORTHERN ESTUARY WATER
(ng/L)

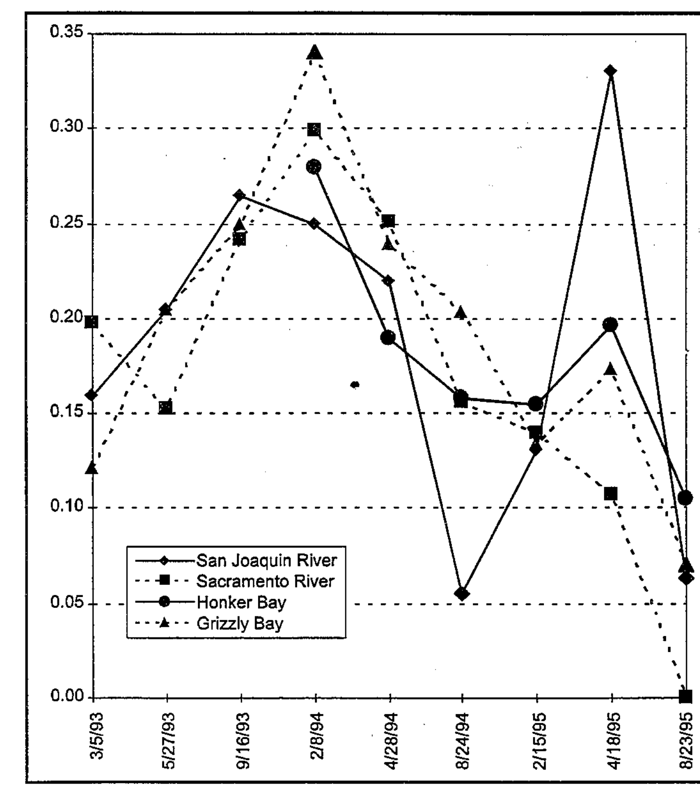

Figure 3
SELENIUM CONCENTRATIONS IN NORTHERN ESTUARY WATER
(ng/L)

carbons), and a few other compounds including diazinon and chlorpyrifos. Data for analysis of long-term trends in water trace organics begin with the 1993 RMP sampling. Diazinon and chlorpyrifos are significant because they have been detected in the northern estuary at concentrations that may be toxic to sensitive organisms. Concentrations of diazinon and chlorpyrifos were higher at three stations in February 1994 than in the other sampling periods (Figures 4 and 5).

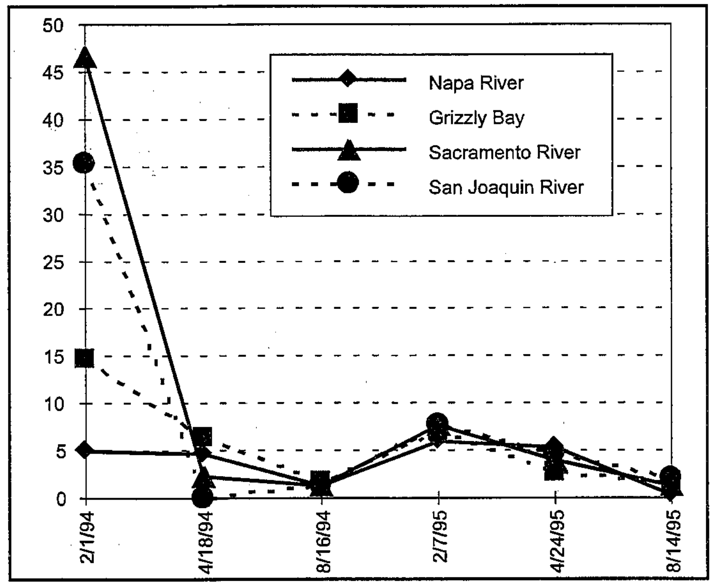

Figure 4
DIAZINON CONCENTRATIONS IN NORTHERN ESTUARY WATER
(ng/L)

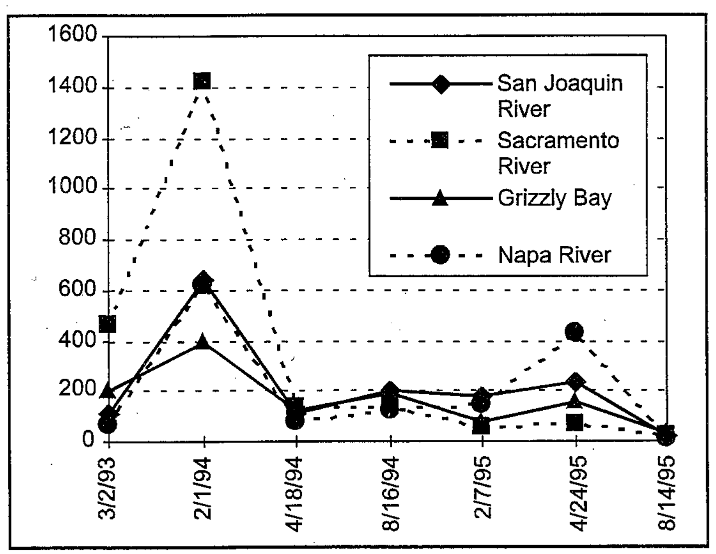

Figure 5
CHLORPYRIFOS CONCENTRATIONS IN NORTHERN ESTUARY WATER
(pg/L)

Aquatic Toxicity

Three different bioassays have been conducted on water samples collected in the wet (usually February) and dry (August) seasons. In 1993, the diatom *Thalassiosira pseudonana* and larval bivalves (mussels or oysters) were used. Beginning in 1994, the mysid *Mysidopsis bahia* was used instead of the diatom. For the mysids, percent survival in 7-day exposures to ambient water is measured. For the larval bivalves, percent normal development in 48-hour exposures is measured. Toxicity is indicated when the endpoint in the ambient water sample is significantly lower than in a clean water control.

In 1993, no toxicity was reported at any of the RMP stations sampled with either the diatom or larval bivalve test. No toxicity has ever been observed in the larval bivalve test at any RMP station. However, from 1994 through February 1997, toxicity to the mysids was observed in 46% of the samples collected from the Sacramento River, San Joaquin River, Grizzly Bay, and Napa River stations (Table 1). Toxicity was less frequent in 1994 and 1995 than in 1996 and 1997. Beginning in February 1996, toxicity occurred in almost all samples at these four stations. At sites monitored farther downstream in the estuary, aquatic toxicity has only occurred in one sample (Red Rock, February 1994) since 1993.

Causes of the toxicity to mysids are not clear. Because of the location near the confluence of the Sacramento and San Joaquin rivers and the time of year that toxicity was observed, dissolved pesticides are suspected. However, since the ambient water tested contains numerous contaminants, it is difficult to tell which contaminants are responsible for the toxicity. Toxicity Identification Evaluations (TIEs) are chemical fractionation procedures that can identify the probable cause of toxicity, but the Regional Monitoring Program does not conduct TIEs on toxic water samples. As shown in Figures 4 and 5, diazinon, chlorpyrifos, and other trace organic contaminants are usually elevated at those same stations during February runoff events. The cause of the toxicity observed in August 1996 is also unclear. Laboratory analyses of those water samples are not yet complete.

Sediment Toxicity

Two different bioassays are conducted on sediments collected during the wet and dry sampling seasons. First, the resident amphipod *Eohaustorius estuarius* is exposed to whole sediment where percent survival is measured over 10 days. In a second test, larval bivalves (mussels or oysters) are exposed to water extracts of sediments (elutriates), where percent normal development is measured over 48 hours.

Table 1
AQUATIC AND SEDIMENT BIOASSAYS AT FOUR NORTHERN ESTUARY RMP SITES
Percent survival for mysids and amphipods. Percent normal development for bivalve larvae.

	Sacramento River			San Joaquin River			Grizzly Bay			Napa River		
		Sediment			Sediment			Sediment			Sediment	
	Aquatic Mysids	Amphi-pods	Bivalve Larvae	Aquatic Mysids	Amphi-pods	Bivalve Larvae	Aquatic Mysids	Amphi-pods	Bivalve Larvae	Aquatic Mysids	Amphi-pods	Bivalve Larvae
Aug 91		85	—		95	—		63*	96		55*	70
April 92		56*	3*		88	5*		50*	94		56*	—
Mar 93		74*	0*		89	0*		57*	0*		61*	65
Sep 93		97	0*		93	0*		84*	39*		83*	76
Feb 94	95	85	1*	73	82*	0*	90	72*	84	63*	68	94
Aug 94	95	82	2*	93	83	1*	90	87	9*	93	76	10*
Feb 95	93	95	0*	83*	80*	0*	98	80*	0*	88	78*	92
Aug 95	93	100	0*	95	96	0*	90	93	39*	88	85*	100
Feb 96	7.5*	92	0*	0*	77*	0*	60*	58*	0*	2.5*	73*	14*
Aug 96	75*	93	0*	73*	96	0*	73*	92	0*	88	93	0*
Jan 97	22.5*			0*			77.5*			72.5*		

* = toxic — = QA problems
Data for 1993 Aquatic bioassays are not included because Mysids were not used.

Toxicity is indicated when there is a significant difference from a home sediment control and when survival is below a minimum detectable difference value.

Sediment toxicity is widespread in the estuary in space and time, and the two tests show different toxicity patterns (Table 1). Data from the BPTCP studies and the Regional Monitoring Program show that between 1991 and 1996, about 25% of the amphipod tests were toxic at the Sacramento and San Joaquin river stations, whereas all of the larval bivalve tests indicated that those sediments were toxic (n=20). About 75% of the tests at Grizzly Bay and Napa River indicated toxicity to amphipods; 70% of the Grizzly Bay and 40% of the Napa River larval bivalve tests were toxic.

Just as with the aquatic toxicity tests, it is not yet clear which contaminants may be causing the sediment toxicity. Sediments also contain mixtures of contaminants, but TIE procedures for sediments are not well developed. Recent statistical analyses suggest that the pesticide chlordane may have been a major factor causing toxicity to amphipods in the 1991-1993 samples. However, chlordane concentrations have decreased since then, and it appears that several metals and DDTs at those stations may be causing toxicity. Trace metals in sediments at the confluence stations may be a major factor in severely reducing normal development of bivalve larvae.

The implications of the aquatic and sediment toxicity for wild populations is not known. Research focused on biological effects of contaminants is a priority of the IEP Contaminants Work Team.

Bioaccumulation

Contaminant concentrations in transplanted bivalves are measured in the Regional Monitoring Program to provide a temporally integrated assessment of bioaccumulation in a portion of the estuary's food web. Since no single species of bivalve tolerates the wide range of salinity covered by RMP stations, mussels (*Mytilus californianus*), oysters (*Crassostrea gigas*), and clams (*Corbicula fluminea*) are deployed in different parts of the estuary. Two times each year, concentrations of trace elements and trace organics are measured in bivalve tissues after a 3-month deployment.

For mussels, data collected in the estuary under the State Mussel Watch Program in 1980-1993 can be combined with RMP data for analysis of long-term trends. As an example, cis-chlordane concentrations at Pinole Point are shown in Figure 6. For this contaminant, which is one of the most abundant chlordane compounds, a clear, gradual trend toward diminished concentrations since 1981 is apparent. p,p-DDE, a major DDT metabolite, shows a similar trend at Pinole Point (data not shown). In contrast, PCBs at Pinole Point have not declined appreciably since 1982 (data not shown).

In the low-salinity water of the northern estuary, clams (*Corbicula fluminea*) are deployed. Historical State Mussel Watch Program data are not available for clams and oysters in the bay, so trend plots for these species begin with 1993. Selenium concentrations in clams are plotted in Figure 7 as an example. Concentrations at these three stations track each other fairly closely. They appear to decline between June 1993 and April 1995 but increase in September 1995.

Additional information on contamination of the estuary's food web will be obtained in 1997 through RMP sampling of contamination in fish tissue. Species commonly caught and consumed that are known to accumulate contaminants are being targeted for sampling, including jacksmelt, white croaker, shiner surfperch, California halibut, striped bass, leopard shark, and white sturgeon.

Acknowledgments

The trace organic contaminant analyses were conducted by Bob Risebrough, Bodega Bay Institute; Wally Jarman, UCSC/University of Utah; and the Geochemical and Environmental Research Group, Texas A&M. Trace metals analyses were conducted by Russ Flegal, UCSC and Brooks-Rand, Ltd., Seattle. Aquatic bioassays were conducted by S.R. Hansen and Assoc. and Dr. Scott Ogle at Pacific EcoRisk Labs, Martinez. Sediment bioassays were conducted by John Hunt and Brian Anderson, UCSC.

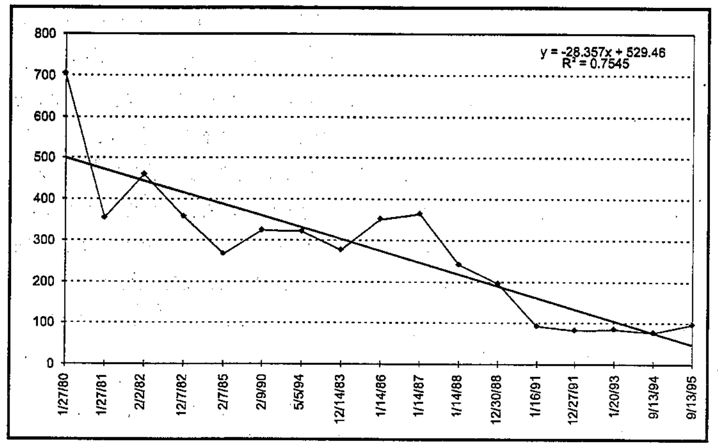

Figure 6
CIS-CHLORDANE CONCENTRATIONS IN MUSSELS AT PINOLE POINT USING RMP AND STATE MUSSEL WATCH DATA
(ng/g lipid)

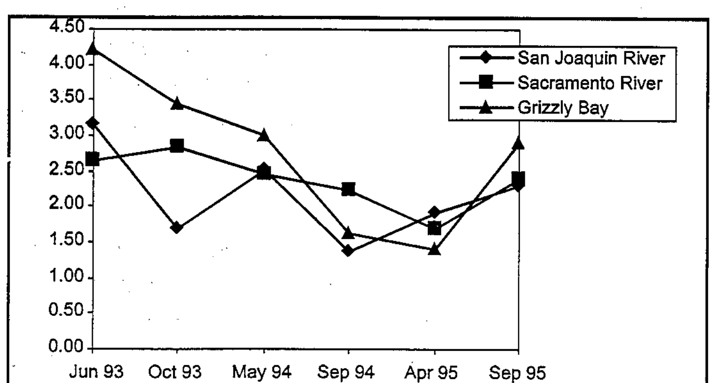

Figure 7
SELENIUM CONCENTRATIONS IN *CORBICULA* IN THE NORTHERN ESTUARY
(µg/g dry weight)

Suisun Marsh Fish Trends

Scott A. Matern, UC-Davis

In 1996, the UC-Davis team conducted 252 otter trawls at twenty-one sites and 84 beach seine hauls at two sites in Suisun Marsh using methods described in Meng *et al* (1994). We conducted an additional 40 trawls during a short-term study designed to examine the effects of day versus night trawling. This report summarizes results of the studies on Suisun Marsh fish sampling for fiscal years 1996 and 1997 funded under DWR contracts B-59998 and B-80900.

During our 1996 sampling we collected over 8,000 fish, averaging 15 fish per trawl and 52 fish per seine haul. Catches of native fishes declined 51%, and exotics declined 19% from 1995, when both groups increased more than twofold (Figure 1). The 12 delta smelt we caught this year were a slight improvement over the 2 from last year, but longfin smelt catches fell from 82 in 1995 to 8 in 1996 (Figure 2). Despite a decline from last year (Figure 3), striped bass young-of-the-year outnumbered every other species by at least two to one. Striped bass adults continued their long-term decline. We caught far less splittail young-of-the-year in 1996 than in 1995 (Figure 4), probably because the rains of 1996 came too late to favor splittail spawning. The 1995 splittail cohort seems to be doing well, though; we caught more splittail "adults" in 1996 than in any year since 1987. Tule perch catches, which have been very low for the past 8 years, hit an all-time low for the second year in a row. Nearly half of the fish collected in our beach seines were inland silversides.

Chinese mitten crabs reached Suisun Marsh in February, and we caught four of them in 1996 (see Kathy Hieb's report in this issue for details on the crab invasion). In April we caught a green sturgeon for the first time in the 18-year history of our Suisun Marsh trawling.

Our day versus night trawling study, conducted during two day/night sessions, showed no significant differences in number of fish per trawl or number of species per trawl. However, some of the more pelagic species appeared to be more susceptible to capture at night. We caught 18 delta smelt during our 20 nighttime trawls and none during the day. Similarly, we collected 32 Pacific herring at night and none during the day. Of the two most common species collected in this study, threadfin shad appeared significantly more often at night (p=0.003), while striped bass did not (p=0.257).

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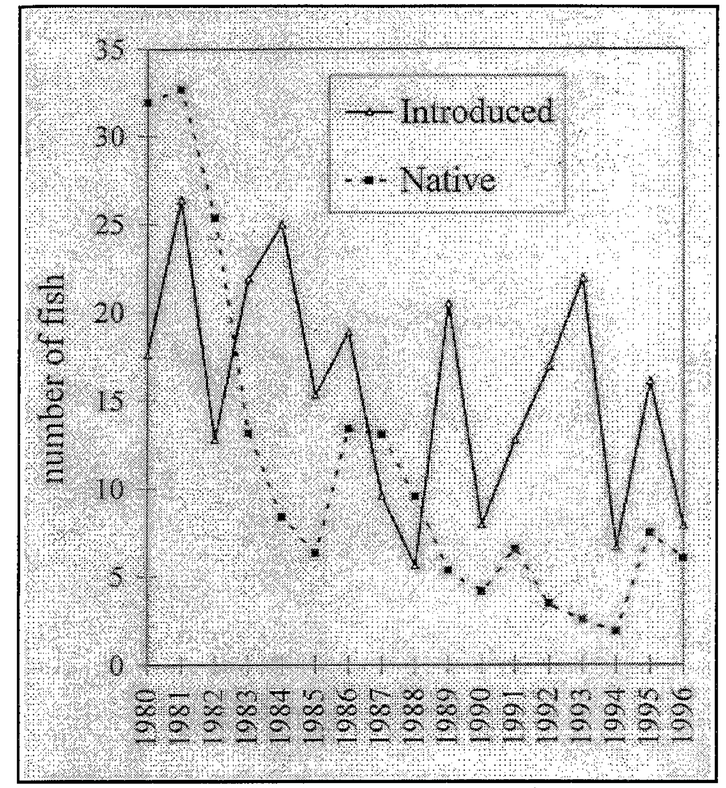

Figure 1
MEAN CATCH PER TRAWL OF NATIVE AND INTRODUCED FISHES IN SUISUN MARSH

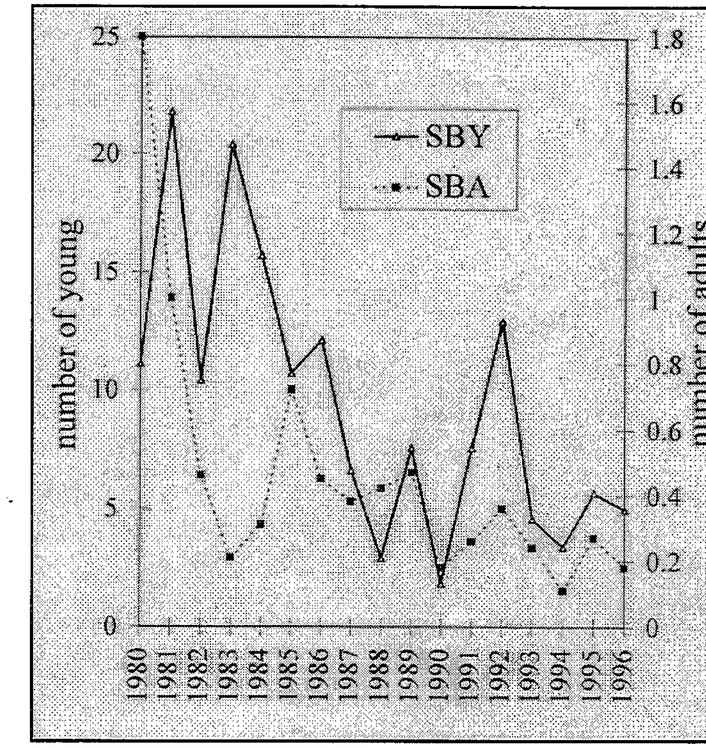

Figure 3
MEAN CATCH PER TRAWL OF YOUNG AND ADULT STRIPED BASS

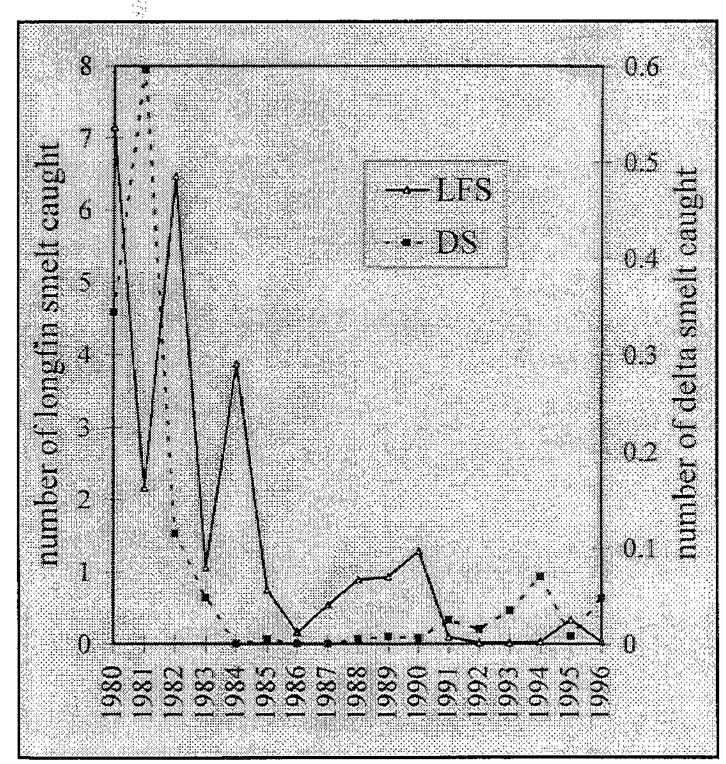

Figure 2
MEAN CATCH PER TRAWL OF LONGFIN SMELT AND DELTA SMELT

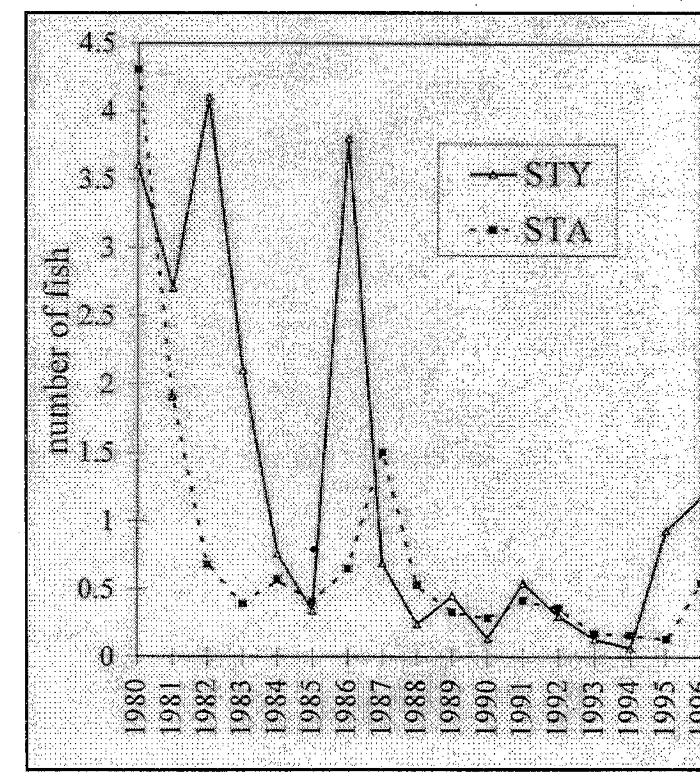

Figure 4
MEAN CATCH PER TRAWL OF YOUNG AND ADULT SPLITTAIL